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[Claim(s)]
[Claim 1] In the industrial robot which has the configuration where the drive-shaft motor which drives a joint part is connected with an arm through a reducer The presumed disturbance torque which said drive-shaft motor receives by using an observer is computed. When the collision ingredient of disturbance torque is computed and the collision ingredient of this disturbance torque exceeds the 1st default value set up beforehand by deducting known disturbance torque from this presumed disturbance torque, Or the collision detection method of the industrial robot characterized by making it judge that birth of the collision was detected to one when the amount of change of the collision ingredient of disturbance torque exceeds the 2nd default value set up beforehand of cases.
[Claim 2] Said 1st default value operates said industrial robot in the state where there is no birth of a collision. The collision detection method of the industrial robot according to claim 1 characterized by making it set up automatically by computing the maximum of the collision ingredient of said disturbance torque at this time, and multiplying this maximum by a predetermined margin value.

[Detailed Description of the Invention]
[0001]
[Field of the Invention] When the arm or end effector which constitutes an industrial robot collides with an obstruction etc., it is related with the collision detection method of the industrial robot which can press down the load at the time of a collision to the minimum.
[0002]
[Description of the Prior Art] When the end effector grasped by the arm itself or this which constitutes an industrial robot collides with an obstruction, The drive-shaft motor which drives

each arm tends to rotate continuously still more according to the movement command set up beforehand, and as a result, a drive-shaft motor will be in a restrained condition, and will continue generating big torque. Since a possibility that the device part of the arm containing a drive-shaft motor and a reducer will be damaged would arise if this state continues for a long time, birth of the collision was detected with a certain technique, and it was made to deal with interrupting the movement command of a drive-shaft motor immediately etc. from before.
[0003] For example, when the disturbance torque in consideration of friction torque was presumed and this presumed disturbance torque became by a disturbance presumption observer beyond default value, he was trying to judge it as what the collision etc. has produced as load being unusual by the method currently indicated by JP,H6-131050,A. Without using the special detector for [, such as a force sensor,] collision detection, the processing on software can detect birth of a collision, and this method can intercept the supplying power to a drive-shaft motor, and can carry out emergency shut down of the arm immediately by this.
[0004]
[Problem to be solved by the invention] However, it sets to the processing on software. [the time when a certain amount of time lag will arise at by the time it detects this on software, after a collision actually occurs, and the supplying power to a drive-shaft motor is intercepted as a result] Since it became what added this time lag at least from actual collision birth time, it stopped, after the end effector grasped by the arm itself or this had sunk into the obstruction, and there was a trouble that the excessive force was applied to the drive system containing a reducer.
[0005] In drawing 2 being the graph which shows the time change after the time of collision birth of the collision ingredient of disturbance torque speaking concretely, The time from the collision birth time T1 to the time T2, i.e., collision detection time, when the collision ingredient of disturbance torque exceeds default value hits time lag. The end effector grasped by the arm itself or this between this time lag will sink into an obstruction, and the excessive force will be applied to the drive system containing a reducer.
[0006] Although the easiest method as a cure which makes this time lag small is reducing default value, if default value is reduced very much to a degree, even when the collision will not actually have occurred, the situation where a judgment which if the collision has occurred mistook is made will arise, the reliability of collision detection will fall, and it is a problem. In detail although drawing 5 is graph which shows time change of the collision ingredient of disturbance torque when the collision has not occurred Between the robot model and the system which are used by a disturbance presumption observer even when the collision has not occurred Since the error by environment, such as a robot's mechanical error and a temperature change, a hand, a setting-out error of a work piece which an operator sets up, etc. exist Always exact disturbance torque is not necessarily presumed and it becomes the thing

included a certain amount of error, and as shown in drawing 5 as a result, the zero with a perfect collision ingredient of disturbance torque do not become. Therefore, when time change of the collision ingredient of the disturbance torque before and behind collision birth serves as graph as shown in drawing 6 and default value (the 1st default value) is reduced very much to a degree in this case, the state where the collision ingredient of disturbance torque exceeds default value also before actual collision birth (collision birth time T1 before) may happen. Therefore, collision detection quick only by reducing default value and positive cannot be performed.

[0007] Moreover, the force concerning the drive system which contains a reducer between time lag becomes larger, as the working speed of the arm of the moment of colliding is quick. Namely, since the degree by which the end effector grasped by the arm itself or this between time lag sinks into an obstruction also becomes larger as the working speed of the arm of the moment of colliding is quick The restitution generated between the end effector and obstruction which were grasped by the arm itself or this in a collision state becomes large, and, as a result, the much more excessive force will be applied to a drive system. Therefore, when the working speed of an arm is quick, it is necessary to detect birth of a collision in short time from the collision birth time T1 especially.

[0008] The time of the end effector which was made in order that this invention might solve the above-mentioned technical problem, and was grasped by the arm itself or this colliding with an obstruction, Time lag after a collision occurs until it detects a collision is lessened, and it aims at offering the collision detection method of the industrial robot which can press down the load at the time of the collision concerning the drive system which, as a result, contains an arm or an end effector, and a reducer to the minimum.

[0009]

[Means for solving problem] In the industrial robot which has the configuration where the drive-shaft motor which drives a joint part is connected with an arm through a reducer in this invention in order to attain the above-mentioned object The presumed disturbance torque which a drive-shaft motor receives by using an observer is computed. When the collision ingredient of disturbance torque is computed and the collision ingredient of this disturbance torque exceeds the 1st default value set up beforehand by deducting known disturbance torque from this presumed disturbance torque, Or the collision detection method of the industrial robot characterized by making it judge that birth of the collision was detected to one when the amount of change of the collision ingredient of disturbance torque exceeds the 2nd default value set up beforehand of cases was offered (Claim 1).

[0010] The presumed disturbance torque which a drive-shaft motor receives by using an observer in the conventional collision detection using an observer is computed. By deducting known disturbance torque called what is called axial interference torque that makes a source

imbalanced torque generated with gravity, a centrifugal force, Coriolis force, inertial force which are generated by motion of other drive shafts, etc. from this presumed disturbance torque An increased part by the collision of disturbance torque, i.e., the collision ingredient of disturbance torque, is computed, and when the collision ingredient of this disturbance torque exceeded the default value set up beforehand, he was trying to judge that birth of the collision was detected. When a collision occurred in the state where the working speed of an arm is slow, it could fully respond also by this conventional collision detection method, but when a collision occurred in the state where the working speed of an arm is quick, the effect by the time lag described previously was not able to be disregarded.

[0011] so, when a collision occurs in the state where the working speed of an arm is quick, in this invention The amount of change of the collision ingredient of disturbance torque became large, and peak time of the amount of change of the collision ingredient of disturbance torque was made to pay one's attention to the characteristic that the collision ingredient of disturbance torque visits earlier than the time exceeding the default value beforehand set up depending on the value of the default value further compared with the collision ingredient of disturbance torque. That is, the amount of change of the collision ingredient of disturbance torque is computed, and also when this amount of change exceeds the default value set up beforehand, it is made to judge that the collision was detected in this invention. When a collision occurs in the state where the working speed of an arm is quick, by this, a collision can be detected earlier than the conventional method [default value / ingredient / of disturbance torque / collision]. However, when an obstruction is a soft thing, for example, an elastic body, or a collision occurs in the state where the working speed of an arm is slow, the amount of change of the collision ingredient of disturbance torque also has the inconvenience that it is small and the situation where the amount of change therefore does not exceed default value arises.

[0012] In order to cope with this, two of the 2nd default value compared with the 1st default value and the amount of change of the collision ingredient of disturbance torque which are measured with the collision ingredient of disturbance torque by this invention are set up beforehand. When the collision ingredient of disturbance torque exceeds the 1st default value set up beforehand, it is made to judge that birth of the collision was detected to one when the amount of change of the collision ingredient of disturbance torque exceeds the 2nd default value set up beforehand of cases. While detection of a collision is attained by this regardless of the working speed of the arm at the time of a collision, or the elastic force of an obstruction, when a collision occurs in the state where the working speed of an arm is quick, especially Time lag after a collision occurs until it detects this can be lessened, and, as a result, time of an overload state of an arm or a drive system can be lessened now. In addition, the amount of change of the collision ingredient of disturbance torque can be easily calculated by carrying out time differential of the collision ingredient of said disturbance torque obtained by the observer.

[0013] By the way, you may make it set up automatically the 1st default value set up in this invention by the method described below. Namely, in invention concerning Claim 2, the 1st default value operates an industrial robot in the state where there is no birth of a collision, computes the maximum of the collision ingredient of the disturbance torque at this time, and set it up automatically by multiplying this maximum by a predetermined margin value. It enables this to set up automatically the 1st different default value for every drive shaft.
[0014]
[Mode for carrying out the invention] One embodiment of this invention is hereafter explained with reference to Drawings. Drawing 1 is the block diagram of the automatic control system which constitutes the drive-shaft control instruments in one embodiment of this invention. The encoder as a position transducer for the servomotor as a drive-shaft motor for one to drive the drive shaft of each arm of an industrial robot and 2 to detect the position of a drive shaft and 3 are the power amplifier as an amplifier among drawing. The servo loop is constituted from the inner side by three-fold loop formation of the current control instruments 4, the speed regulating device 5, and position-control equipment 6. 10 is a command position generator which was called for in order that an industrial robot might operate proper based on the limiting value of a target position, a departure position, claim speed, and acceleration etc. and which sometimes outputs the command position of each drive shaft of ****. When 7 collides with the obstruction which the end effector which was grasped by the arm 23 or arm 23 to which the collision detection method of this invention is applied, and which is not illustrated does not illustrate, it is collision detection equipment which detects this. 8 is position loop gain alteration equipment into which a position loop gain is changed at the time of collision detection. 9 is command repositioning equipment into which a command position is changed at the time of collision detection. On the other hand, drawing 4 is the key map of a spring-mass system showing the relation of a servomotor 1, the rotation reducer 22, and an arm 23.
[0015] When the performance of this automatic control system is explained, [position-control equipment 6] The servomotor 1 according to the operation program which the command position generator 10 generated sometimes The command position of ****, Difference with the position feedback 11 as a current position read from the encoder 2 attached to the servomotor 1 is taken, and he considers it as the position error 14, and is trying to output the speed command 15 which multiplied this position error 14 by the position loop gain, and was called for. The speed command 15 to which the speed regulating device 5 was outputted from position-control equipment 6, Difference with the speed feedback 12 called for by differentiating the current position read from the encoder 2 from Differentiator S is taken, and he considers it as a velocity error, and is trying to output the current command 16 based on this velocity error. The current control instruments 4 take the difference of the current command 16 outputted from the speed regulating device 5, and the current feedback 13 as

actual current which flows into the servomotor 1 detected with the current detection machine 17, and he is trying to output motor current to a servomotor 1 based on this.

[0016] Collision detection equipment 7 presumes disturbance torque by a disturbance presumption observer, and when the collision ingredient of the disturbance torque computed based on this presumed disturbance torque becomes beyond default value, he is trying to be equipment with which the collision detection method of this invention is applied, and to judge it to be what the collision has produced. Although a servo loop tends to output bigger torque (current command 16) than usual to a servomotor 1 at the time of a collision, since the position of a servomotor 1 hardly changes with collisions actually, most values of the speed feedback 12 serve as zero. Therefore, the value of the current command 16 outputted from the speed regulating device 5 and the speed feedback 12 is supervised. It is twisted based on these values, compute an amount, and this amount of torsion is converted into the disturbance torque added to an arm 23. If known disturbance torque called what is called axial interference torque that makes a source imbalanced torque generated with gravity, a centrifugal force, Coriolis force, inertial force which are generated by motion of other drive shafts, etc. is deducted from this reduced value, an increased part by the collision of disturbance torque, i.e., the collision ingredient of disturbance torque, is computable.

[0017] Drawing 3 is graph which shows the timing of the collision detection in this embodiment, the (a) figure shows time change of the collision ingredient of disturbance torque, and the (b) figure shows time change of the amount of change of the collision ingredient of disturbance torque. (a) (b) both drawings of a horizontal axis are time, and a vertical axis is [figure / (a)] the amount of change of the collision ingredient of disturbance torque about the collision ingredient of disturbance torque, and the (b) figure. (a) The collision ingredient of disturbance torque shown in drawing computes the presumed disturbance torque which a drive-shaft motor receives by using an observer as mentioned above. It is obtained as an increased part by the collision of disturbance torque by deducting known disturbance torque called what is called axial interference torque that makes a source imbalanced torque generated with gravity, a centrifugal force, Coriolis force, inertial force which are generated by motion of other drive shafts, etc. from this presumed disturbance torque. Moreover, the amount of change of the collision ingredient of disturbance torque shown in the (b) figure can be obtained by carrying out time differential of the collision ingredient of said disturbance torque obtained by the observer.

[0018] The graph of the (a) figure which shows the collision ingredient of disturbance torque is the same as that of above-mentioned drawing 2 . That is, T1 is collision birth time and T2 is the time when the collision ingredient of the disturbance torque as collision detection time exceeded default value (the 1st default value). Although a collision is detected so quickly that this value is small, if it is made very small to a degree too much, even when the collision will

not actually have occurred, the situation where a judgment which if the collision has occurred mistook is made produces the 1st default value. Therefore, also in order not to reduce the reliability of collision detection, the 1st default value needs to calculate a proper value by conducting a collision experiment etc. in advance, but it is also possible to make it set up automatically to mention later.

[0019] On the other hand, generally, a peak magnitude becomes large and the amount of change of the collision ingredient of disturbance torque shown in the (b) figure appears, so that the working speed of an arm is quick. As for this, the amount of change of the collision ingredient of disturbance torque shows the size of the impulsive force at the time of a collision, and it is because the impulsive force at the time of a collision is so large that the working speed of an arm is quick. Then, default value (the 2nd default value) is defined beforehand, and when the amount of change of the collision ingredient of disturbance torque exceeds this 2nd default value, it is made to judge that birth of the collision was detected. When the 1st default value is set as a proper value, the time of the peak magnitude of the amount of change of the collision ingredient of disturbance torque becomes earlier than the time T2 when the collision ingredient of disturbance torque exceeded the 1st default value. Since the time T3 when the amount of change of the collision ingredient of disturbance torque exceeded the 2nd default value in this case with the natural thing becomes earlier than T2 Birth of a collision can be early detected now from the case where the collision ingredient of the conventional disturbance torque is used, by using the amount of change of the collision ingredient of disturbance torque despite ****.

[0020] [when a collision occurs in the state where the working speed of an arm is quick, can detect birth of a collision early rather than before by using an above-mentioned method, but] When the collision occurred in the state where the working speed of an arm is slow, or when an obstruction is a soft thing, for example, an elastic body The impulsive force at the time of a collision is small, and since the peak magnitude of the amount of change of the collision ingredient of disturbance torque therefore becomes small, the situation where collision detection cannot be performed arises only in the amount of change of the collision ingredient of disturbance torque.

[0021] Then, when the 1st default value to which two of the 2nd default value compared with the 1st default value and the amount of change of the collision ingredient of disturbance torque which are measured with the collision ingredient of disturbance torque were beforehand set, and the collision ingredient of disturbance torque was set beforehand is exceeded, Or it was made to judge that birth of the collision was detected to one when the amount of change of the collision ingredient of disturbance torque exceeds the 2nd default value set up beforehand of cases. Thus, while collision detection becomes possible regardless of the working speed of the arm at the time of a collision, or the elastic force of an obstruction by using together the

amount of change of the collision ingredient of disturbance torque, and the collision ingredient of disturbance torque When a collision occurs in the state where the working speed of an arm is quick, especially, time lag after a collision occurs until it detects this can be lessened, and time until an arm stops as a result can be lessened.

[0022] When birth of a collision is detected in collision detection equipment 7, from an encoder 2, command repositioning equipment 9 inputs the current position of a servomotor 1, and outputs this current position to the command position generator 10 as a command position at the time of a collision. The command position generator 10 is usually outputted to position-control equipment 6 as mentioned above according to an operation program etc. by making into a command position the current position of the servomotor 1 of a servomotor 1 inputted from command repositioning equipment 9 at the time of collision detection although the command position of **** was sometimes generated. Thereby, since the position error 14 it is the difference of a command position and a current position at whose time of a collision serves as zero, the speed command 15 which multiplies this by a position loop gain and for which it is asked also serves as zero, and when braking torque occurs in a servomotor 1 as a result, operation of an arm 23 is suspended promptly. Therefore, the pile lump to an arm 23 or the obstruction of an end effector which is not illustrated will be suppressed to the minimum.

[0023] [position loop gain alteration equipment 8] when birth of a collision is detected in collision detection equipment 7 A preset value is outputted to position-control equipment 6 at the time of the collision of a position loop gain, position-control equipment 6 receives the input of a preset value at the time of this collision, and the initial-setting value of the position loop gain memorized in position-control equipment 6 is changed into a preset value at the time of a collision. A position loop gain is a constant of proportion used when computing the speed command 15 from the position error 14, the rigidity of a drive shaft becomes high, and therefore the flattery nature of a drive shaft to a command position becomes good so that this value is large, but the load conversely applied to a servomotor 1 or a reducer 22 becomes large. [in order to improve flattery nature of a drive shaft during operation of an arm 23, it is desirable to take a large position loop gain, but] when a servomotor 1 will be in a restrained condition at the time of a collision The life of a reducer 22 is contracted, or when the worst, the drive system containing a reducer 22 is made damaged by the increase in the load which requires a position loop gain for the reducer 22 by a large thing.

[0024] Then, by changing a position loop gain into a preset value from the initial-setting value under arm operation at the time of a collision smaller than this initial-setting value at the time of a collision A speed command is reduced, therefore the rigidity of a drive shaft is reduced, when the arm 23 which collided with the obstruction as a result is pulled back by stability to a collision position at nature, a pile lump state is canceled and the load therefore applied to a reducer 22 comes to be reduced.

[0025] Although the arm 23 which collided with the obstruction needs to make a preset value small to the grade pulled back by nature to a collision position according to stability at the time of the collision of a position loop gain If it is made extremely small too much, it becomes impossible to be unable to oppose gravity with an arm's own weight, and when the worst, the situation where an arm 23 will fall will occur. Therefore, it is necessary to compensate an influenced part of gravity at worst about a preset value at the time of the collision of a position loop gain. [after taking this point into consideration, a preset value may specify a predetermined value beforehand at the time of the collision of a position loop gain, but] You may make it change a position loop gain by specifying the predetermined ratio beforehand and multiplying the initial-setting value of a position loop gain by this ratio specified beforehand at the time of a collision.

[0026] A preset value is experimentally calculated at the time of the collision that an arm 23 is pulled back by nature to a collision position according to stability, and an arm 23 does not fall under the effect of gravity, by giving predetermined load to an end effector and specifically generating a collision state actually. Or since it will become possible to ask for the ratio to the initial-setting value of a preset value at the time of a collision if two or more data is obtained by repeating the same experiment, a position loop gain is changed by multiplying the initial-setting value of a position loop gain by this ratio at the time of a collision.

[0027] By the way, [the 1st default value] although birth of a collision is detected so quickly that this value is small as stated previously [since the situation where a judgment which if the collision has occurred mistook is made arises even when the collision will not actually have occurred, if it is made very small to a degree too much, also in order not to reduce the reliability of collision detection, it is required to calculate the value of the 1st proper default value by conducting a collision experiment in advance, but] Here, an example of a method which sets up the value of the 1st default value automatically is explained based on the flowchart shown in drawing 7 .

[0028] An industrial robot is operated according to a actual operation program, and processing specified with the flowchart shown in drawing 7 in robot control instruments is performed in the meantime. First, maximum Tmax of the collision ingredient of disturbance torque It initializes (step 31). Next, the collision ingredient T of disturbance torque is computed based on the minimum dimension observer (step 32). The collision ingredient T of disturbance torque is the maximum Tmax in this event. If large (step 33Y), it is the new maximum Tmax about the collision ingredient T of this disturbance torque. It progresses to step 35, after replacing (step 34). On the other hand, the collision ingredient T of disturbance torque is the maximum Tmax in this event. If small (step 33N), it will progress to step 35 as it is. And at step 35, if the operation program is not completed, processing after step 32 is performed again, and on the other hand, if the operation program is completed, it will progress to step 36.

[0029] To the last, it is the maximum Tmax in this event in step 36. It is judged as the maximum in this operation program. That is, drawing 8 is time change and Maximum Tmax of the collision ingredient of disturbance torque when the collision has not occurred. The greatest peak magnitude is Maximum Tmax by making the processing shown in the flowchart of drawing 7 perform, although it is the graph which shows a relation. It asks by carrying out. And maximum Tmax The value acquired by multiplying by a predetermined margin value is memorized as the 1st default value. Here, margin values are one or more numerical values, and after taking a safety factor into consideration, they are set up. that is, when it is in the state which a collision does not generate, it is below the 1st default value that is the value always acquired when the collision ingredient of disturbance torque multiplied maximum by a predetermined margin value -- a margin value is set up to be. Drawing 9 is time change and Maximum Tmax of the collision ingredient of disturbance torque when the collision has occurred. It is the graph which shows a relation with the 1st default value acquired by multiplying by a predetermined margin value. It can be made small, securing the reliability of collision detection by setting up a proper margin value, spacing, i.e., the time lag, of the collision birth time T1 and the collision detection time T2.

[0030] In the above, one embodiment of this invention was explained. Although the above-mentioned embodiment explains the case where this invention is applied to the drive shaft of an industrial robot If it is the thing of a form which operates the member by which the drive-shaft motor which drives a joint part is equivalent to an arm or this through a reducer, it is applicable also to the machine tool which can develop the technique of this invention easily also to things other than an industrial robot, for example, is using the servomotor and the reducer for a drive shaft.

[0031]

[Effect of the Invention] In the industrial robot which has the configuration where the drive-shaft motor which drives a joint part is connected with an arm through a reducer according to this invention The presumed disturbance torque which a drive-shaft motor receives by using an observer is computed. When the collision ingredient of disturbance torque is computed and the collision ingredient of this disturbance torque exceeds the 1st default value set up beforehand by deducting known disturbance torque from this presumed disturbance torque, Or since it was made to judge that birth of the collision was detected to one when the amount of change of the collision ingredient of disturbance torque exceeds the 2nd default value set up beforehand of cases While collision detection becomes possible regardless of the working speed of the arm at the time of a collision, or the elastic force of an obstruction, when a collision occurs in the state where the working speed of an arm is quick, especially Time lag after a collision occurs until it detects this can be lessened, and, as a result, time of an overload state of an arm or a drive system can be lessened now.

[0032] Especially in invention concerning Claim 2, [the 1st default value] Since it was made to set up automatically by operating an industrial robot in the state where there is no birth of a collision, computing the maximum of the collision ingredient of the disturbance torque at this time, and multiplying this maximum by a predetermined margin value The 1st different default value for every drive shaft will be set up automatically, and the reliability of collision detection will improve.

[0033] Since birth of a collision would be quickly detected even when an arm or an end effector collides with an obstruction with quick working speed by the above, it became what can press down the load at the time of the collision concerning the drive system containing an arm or an end effector, and a reducer to the minimum.

[Brief Description of the Drawings]

[Drawing 1] It is the block diagram of the automatic control system of an industrial robot with which the collision detection method of the industrial robot in this invention is applied.

[Drawing 2] It is the graph which shows time change of the collision ingredient of disturbance torque.

[Drawing 3] It is the graph which shows the timing of the collision detection in the embodiment of this invention, and the (a) figure shows time change of the collision ingredient of disturbance torque, and the (b) figure shows time change of the amount of change of the collision ingredient of disturbance torque.

[Drawing 4] It is the key map of a spring-mass system showing the relation of a servomotor 1, the rotation reducer 22, and an arm 23.

[Drawing 5] It is the graph which shows time change of the collision ingredient of disturbance torque when the collision has not occurred.

[Drawing 6] It is the graph which shows time change of the collision ingredient of the disturbance torque before and behind collision birth.

[Drawing 7] It is the flowchart which shows an example of a method which sets up automatically the value of the 1st default value in this invention.

[Drawing 8] Time change and maximum Tmax of the collision ingredient of disturbance torque when the collision in this invention has not occurred It is the graph which shows a relation.

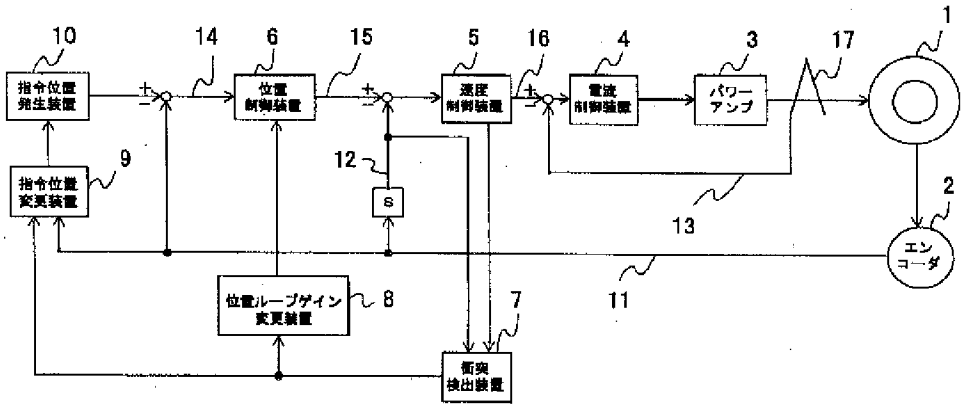
[Drawing 9] Time change and maximum Tmax of the collision ingredient of disturbance torque when the collision in this invention has occurred It is the graph which shows a relation with the 1st default value acquired by multiplying by a predetermined margin value.

[Explanations of letters or numerals]

1 Drive-Shaft Motor (Servomotor)

2 Position Transducer (Encoder)
3 Power Amplifier
4 Current Control Instruments
5 Speed Regulating Device
6 Position-Control Equipment
7 Collision Detection Equipment
8 Position Loop Gain Alteration Equipment
9 Command Repositioning Equipment
10 Command Position Generator
11 Position Feedback
12 Speed Feedback
13 Current Feedback
14 Position Error
15 Speed Command
16 Current Command
17 Current Detection Machine
22 Reducer
23 Arm

[Drawing 1]



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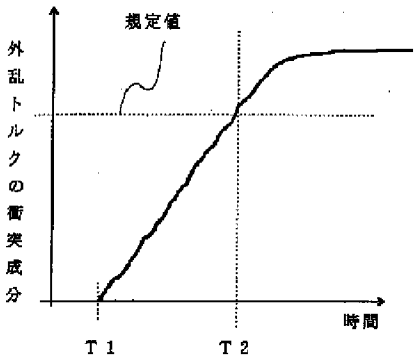

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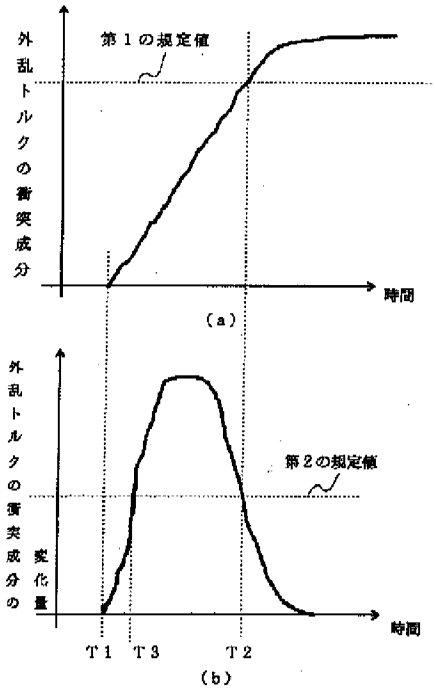

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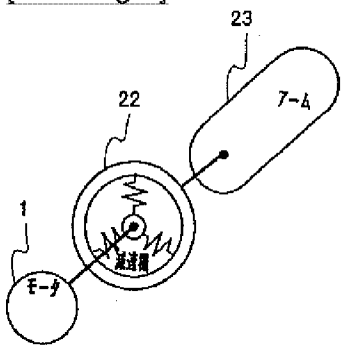

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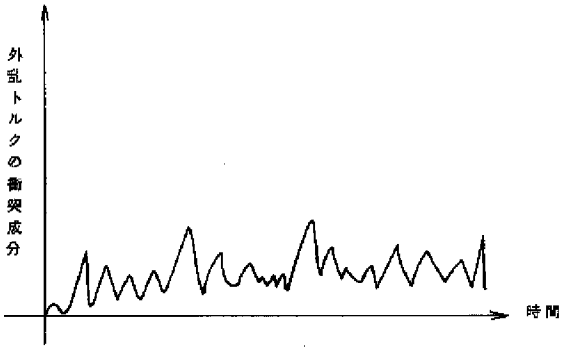

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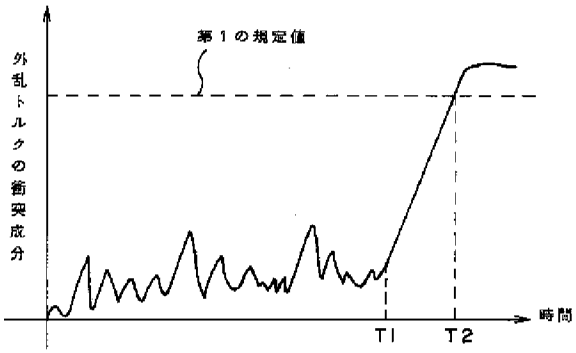

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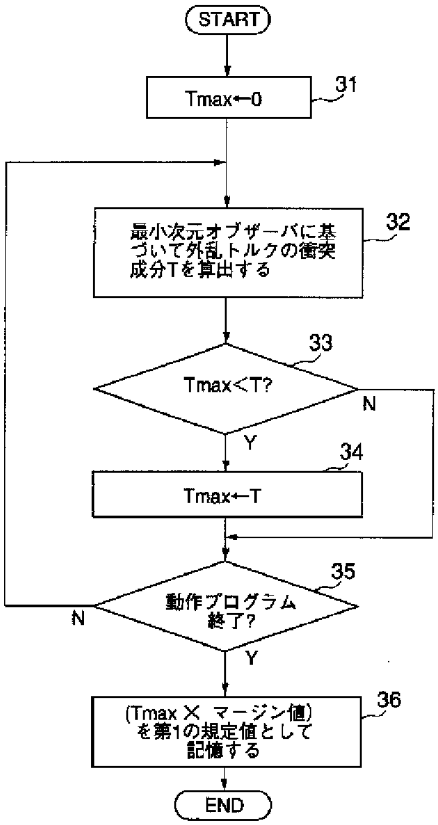

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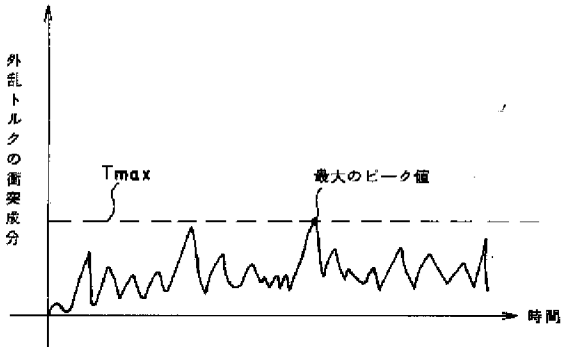

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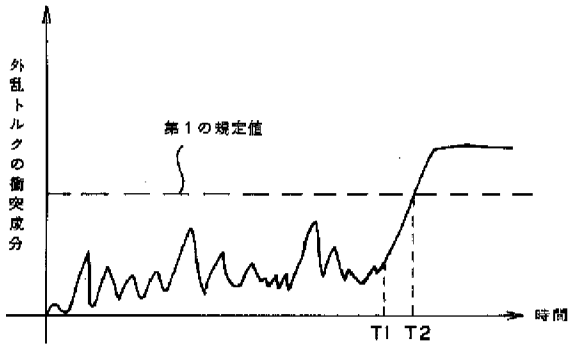

[Translation done.]